Amendments to the Specification:

Please replace paragraph beginning at page 3, line 3, with the following rewritten paragraph:

-- The current invention provides a method and apparatus for communicating two or more channels of DMT modulated data within the same frequency spectrum, thus providing symmetrical bandwidth for upstream and downstream communication across a communication medium. The apparatus may be used for dual channel or multi-channel communications. The method may be implemented on a physical modem or a logical modem with the logical modem including a digital signal processor (DSP) coupled to an analog front end (AFE). The communication medium may include: wired, wireless and optical. Orthogonality in either the time or frequency domains is injected into the individual symbols associated with each DMT tone set or between successive tone sets using a unique code, e.g. Walsh code, assigned to each transmitted channel. The mutual orthogonality of these codes allows two or more channels to be supported in either an upstream or downstream direction using a DMT line code, in connection with any of the various X-DSL protocols including: G.Lite, ADSL, VDSL, SDSL, MDSL, RADSL, HDSL, etc. --

Please replace paragraph beginning at page 5, line 10, with the following rewritten paragraph:

-- The current invention provides a method and apparatus for communicating two or more channels of DMT modulated data within the same frequency spectrum, thus providing symmetrical bandwidth for upstream and downstream communication across a communication medium. The apparatus may be used for dual channel or multi-channel communications. The method may be implemented on a physical modem or a logical modem with the logical modem including a digital signal processor (DSP) coupled to an analog front end (AFE). The communication medium may include: wired, wireless and optical. Orthogonality in either the time or frequency domains is injected into the individual symbols associated with each DMT tone set or between successive tone sets using a unique code, e.g. Walsh code, assigned to each transmitted channel. The mutual orthogonality of these codes

allows two or more channels to be supported in either an upstream or downstream direction using a DMT line code, in connection with any of the various X-DSL protocols including: G.Lite, ADSL, VDSL, SDSL, MDSL, RADSL, HDSL, etc. The present invention provides a signal processing architecture that supports scalability of central office (CO) ~~/~~ or, Digital Loop Carrier (DLC) ~~/~~ or, Optical Network Units (ONU) resources, and allows a significantly more flexible hardware response to the evolving X-DSL standards without over committing of hardware resources. As standards evolve hardware may be reconfigured to support the new standards. --

Please replace paragraph beginning at page 11, line 23, with the following rewritten paragraph:

--FIG. 4 is an expanded hardware view of the digital signal processor portion (DSP) of the line card shown in FIG. 3. Subcomponents of each of the DSP Pad 316, the FTE 322, the Deframer-decoder 332, the framer-encoder 336 and the ~~AFE~~ ATM PAD 340 are shown. --

Please replace paragraph beginning at page 11, line 26, with the following rewritten paragraph:

-- On the upstream packet path, the ~~AFE~~ DSP PAD includes a first-in-first-out (FIFO) buffer 400 where upstream packets from the AFEs are stored and a cyclic prefix remover 404. After removal of the cyclic prefix each packet is then passed to the DFT mapper 424. The DFT mapper is coupled to the input memory portion of the FTE via a multiplexer 420. The mapper handles writing of each sample set from a packet into the input memory in the appropriate order. The mapper may also handle such additional functions as time domain equalization (TEQ) filtering which is a digital process designed to normalize the impact of differences in channel response. The filter may be implemented as an FIR filter. The input memory comprises two portions 416 and 418. Multiplexer 420 provides access to these memories. While one sample set, e.g. time or frequency domain data, is being written from the upstream or downstream data paths into one of the memories the contents of the other of the memories are written into the row and column component 412 of the FTE 322. Once the

DFT is completed by the row and column component the frequency domain coefficients generated thereby are stored in either of portions 410-412 of the output memory of the FTE. These coefficients correspond with each of the DMT sub carriers or tones. A demultiplexer 408 handles the coupling of the output memory to either the next component of the upstream path, i.e. the deframer-decoder 332 or of the downstream path. Next on the upstream path, the device packet with header and data portions and optional control portion is passed to the remaining components of the upstream path. These include the gain scalar and optional forward error correction (FEQ) 426, the Walsh decoder 338, the tone decoder 428, the tone re-orderer 430 and the deframer 434. --

Please replace paragraph beginning at page 12, line 15, with the following rewritten paragraph:

-- A multiplexer ~~430~~ 432 couples the deframer input to either the tone reorderer 430 or to the output memory of the FTE. Each of these components is individually configurable on a per channel basis using tables stored locally in registers within each component, or within memory 328. The access to these tables/registers is synchronized by the logic in each of the components which responds to header or control information in each upstream packet to alter tone ordering/re-ordering, gain scaling constants per-tone per-channel, and FEQ constants per-tone per-channel. The processor 334 may initialize all the registers. From the deframer packets are passed to the FIFO buffer 450 which is part of ATM PAD 340. --

Please replace paragraph beginning at page 13, line 7, with the following rewritten paragraph:

-- On the downstream path a FIFO buffer 452 within the ~~AFE~~ ATM PAD 340 holds incoming packets. These are passed to the components in the Framer and Encoder module 336 for processing. The components of that module include the framer 440, tone orderer 442, tone encoder 444, Walsh encoder 342 and gain scalar 446. They are coupled via a multiplexer 448 to the IDFT mapper 422. As was the case with the deframer, the framer will

use protocol specific information associated with each of these channels to look for different frame and super frame boundaries. The tone orderer supports varying number of tones, bytes per tone and gain per tone for each of the X-DSL protocols. For example the number of tones for G.Lite is 128, for ADSL is 256 and for VDSL 2048. The number of bits to be extracted per tone is read from the tone-ordering table or register at the initiation of processing of each packet. For example as successive packets from channels implementing G.Lite, ADSL and VDSL pass through the DMT Tx engine the number of tones will vary from 128 for G.lite, to 256 for ADSL, to 2048 for VDSL. In the encoder 444 constellation mapping is performed based on the bit pattern of each packet. The output is a two dimensional signal constellation in the complex domain. --

Please replace paragraph beginning at page 13, line 22, with the following rewritten paragraph:

-- Next in the IDFT mapper each device packet is correlated with a channel and protocol and mapped into input memory via a connection provided by multiplexer 420. The mapping is in a row and column order. Next in the FTE, the complex digital symbols DMT symbols are modulated into carriers or tones in the row and column transform component 414 and placed in either portion 410 or 412 of output memory having been transformed from the frequency to the time domain. The dimensions of the row and column transforms vary on a channel specific basis. Next a packet with the memory contents, i.e. the digitized DMT symbols transformed to the time domain is passed as a packet via demultiplexer 408 to the DSP FIFO buffer 406. This is part of DSP PAD 316. Individual packets are moved from this buffer to the cyclic prefix component 402 for the addition of the appropriate prefix/suffix. The cyclic prefix component is responsive to the device packet header which identifies the channel for which data is being processed. This can be correlated with the required prefix/suffix extensions for the protocol associated with the channel on the basis of parameters 326 stored in main memory 328 or within dedicated registers in the component. For example the cyclic extension for G.Lite is 16, for ADSL 32, and for VDSL 320. --

Please replace paragraph beginning at page 15, line 5, with the following rewritten paragraph:

-- FIGS. 6B~~C~~ and 6C are graphs of the line code in which multiple access is accomplished via redundancy in the frequency domain and the time domain respectively, to enable symmetrical use of the frequency ranges shown in FIG. 6A. In FIG. 6B the combined RN tones of both the upstream and downstream frequency ranges 600 and 602 are used for both upstream and downstream communications. Each individual tone 604, 606-612 for example contains redundancy of order R within the frequency domain for a total of RN tones. The tones are shown as stacked, consisting of a single symbol which corresponds ~~which corresponds~~ with both the upstream and downstream component of the 2 channels communicated on the shared communication medium. For the case of two channels sharing the communication medium each upstream and downstream tone is redundantly expressed in at least two tones. Which tones contain redundant data is information which the Walsh decoder shown in the previous FIG. 5 requires in order to remove redundancy from digital DMT symbols in the frequency domain which it receives from the DFT 502A-B. The redundancy is implemented with the appropriate sign convention to maintain orthogonality, between the two or more channels which share the combined tone sets 600 and 602. --

Please replace paragraph beginning at page 15, line 29, with the following rewritten paragraph:

-- FIGS. 7A~~B~~ and 7B show an embodiment of the transmit and receive logic associated with redundancy for DMT line codes implemented in the frequency and time domains respectively.

Two logical modems are shown identical to the modems shown in FIG. 5. The first logical modem includes DSP 218A together with AFE 214A. The second logical modem includes DSP 218B together with AFE 218B. The modems are coupled to one another via a common communication medium, e.g. subscriber line 262. Exploded views of a hardware implementation of the multiple access decoders 338A-B and encoders 342A-B are shown within their corresponding modem. In the embodiment shown the encoders take an incoming set of DMT symbols for each tone. Each symbol may be expressed as a complex number x+ij.--

Please replace paragraph beginning at page 16, line 6, with the following rewritten paragraph:

--In FIG. 7A multiple access via frequency domain redundancy is implemented using the DMT line code as discussed above in FIG. 6B. In this embodiment the incoming data stream is framed in framer 440A. Individual portions of the framed data are allocated to a corresponding tone bin by the tone ordere~~d~~r 442A and passed to the DMT tone encoder 444A where they are mapped to a DMT symbol and expressed as a complex number. In the example shown the number of DMT tones processed in each tone set by the tone ordered 442A is two shown within the frame boundaries 700A-702A. The two DMT tones are labeled A_1, A_0 with A_0 the first of the DMT symbols to be transmitted. Redundancy in the frequency domain is injected to this set of tones by appropriate switching of the Walsh encoder 342A in accordance with the selected Walsh code driving the demultiplexer 710A and multiplexer 712A which switch each incoming symbol of the symbol set from a non-inverted path 718A to an inverted path 716A which includes inverter 714A. This implements redundancy R of order 2 in the frequency domain for a total of RN tones, in this case 4 within a single tone set. The encoder generates a tone set with twice the number of tones per tone set as input as shown within frame boundaries 704A-706A. In the example shown these are: $-A_1$, A_1, $-A_0$, A_0, for a total of 4 DMT symbols. The sign convention corresponds with a Walsh code of +/-1s assigned to DSP 218A for transmission of data. The Walsh code for the DSP 218B is orthogonal to that assigned to DSP 218A. The sequence of DMT tones transmitted by that modem is: B_1, B_1, B_0, B_0. The decoders 338A-B include corresponding buffers 722A-B and 720A-B, along with summers 724A-B and corresponding dividers 726A-B. The decoder accepts 4 DMT symbols each of which includes contribution from both the transmit path of the opposite modem as well as from Self NEXT from the modems own transmitter with which the DMT tone set is shared. In the example shown the received tones are: $A_0 + B_0$, $-A_0 + B_0$, $A_1 + B_1$, $-A_1 + B_1$. The decoder decodes the incoming sets of tones redundant in the frequency domain. The redundancy and coding is established during session set up for each channel. The redundancy is removed and the appropriate received DMT symbol sets B_0, B_1 are passed to the tone decoder ~~430A~~ 428A for decoding. The tone reorderer 430A performs reordering of the tones and the deframer 434A deframes the DMT symbols. On the receive

path of the opposite modem the decoder ~~428B~~ 338B decodes with an orthogonal Walsh code. In alternate embodiments of the invention redundancy in the frequency domain may be implemented at the tone orderer. In alternate embodiments of the invention code sequences other than Walsh coding may be implemented to introduce orthogonal redundancy into the channels which share a common set of DMT tones.—

Please replace paragraph beginning at page 3, line 3, with the following rewritten paragraph:

--In FIG. 7B multiple access via time domain redundancy is implemented using the DMT line code as discussed above in FIG. 6C. In this embodiment the incoming data stream is framed in framer 440A. Individual portions of the framed data are allocated to a corresponding tone bin by the tone order~~ed~~r 442A and passed to the DMT tone encoder 444A where they are mapped to a DMT symbol and expressed as a complex number. In the example shown the number of DMT tones processed in each tone set by the tone ordered 442A is two shown within the frame boundaries 700A-702A. The two DMT tones are labeled A_1, A_0 with A_0 the first of the DMT symbols to be transmitted. Redundancy in the time domain is injected to this set of tones by appropriate switching in accordance with the selected Walsh code of the Walsh encoder 342A. An additional multiplexer 720A and input buffers 720A-722A have been added to the encoder enabling it to implement redundancy R of order 2 in the time domain. The encoder 342A generates two tone sets with the same number of tones as the input tone set for a total of RN tones, in this case 4. In the example shown these are: $-A_1$, A_0 in a second tone set with boundaries 732A-734A and A_1, A_0, in a first tone set with boundaries 730A-732A. The sign convention corresponds with a Walsh code of +/- 1s assigned to DSP 218A for transmission of data. The Walsh code for the DSP 218B is orthogonal to that assigned to DSP 218A. The sequence of DMT tones transmitted by that modem is: B_1, B_1, B_0, B_0. The decoders 338A-B include corresponding buffers 722A-B and 720A-B, along with summers 724A-B and corresponding dividers 726A-B. The decoder accepts 4 DMT symbols each of which includes contribution from both the transmit path of the opposite modem as well as from Self NEXT from the modems own transmitter with which the DMT tone set is shared. In the example shown the received tones are from

first to last: $A_0 + B_0$, $-A_0 + B_0$, $A_1 + B_1$, $-A_1 + B_1$. The decoder decodes the incoming sets of tones redundant in the time domain. The redundancy and coding is established during session set up for each channel. The redundancy is removed and the appropriate received DMT symbol sets B_0, B_1 are passed to the tone decoder ~~430A~~ 428A for decoding. The tone reorderer 430A performs reordering of the tones and the deframer 434A deframes the DMT symbols. On the receive path of the opposite modem the decoder ~~428B~~ 338B decodes with an orthogonal Walsh code. In alternate embodiments of the invention redundancy in the time domain may be implemented at the output of the IDFT instead of the input as discussed above. In alternate embodiments of the invention code sequences other than Walsh coding may be implemented to introduce orthogonal redundancy into the channels which share a common set of DMT tones.--

Please replace paragraph beginning at page 25, line 7, with the following rewritten paragraph:

-- ~~The current invention provides a~~ A method and apparatus for communicating ~~two or more~~ multi-tone modulated upstream and downstream channels of communication data between a pair of communication devices ~~DMT modulated data within the same~~ utilizing a common set of tones ~~frequency spectrum.~~ for the upstream and downstream channels. The pair of communication devices each include a digital stage configured to assign mutually orthogonal code sequences for encoding and decoding the upstream and downstream channel respectively. The transmit path of the digital stage of each communication device is configured to generate redundancy in the associated communication data in either the time or frequency domain and to encode the redundant communication data with the mutually orthogonal code sequence prior to transmission thereby allowing the communication devices to share a common frequency spectrum. ~~, thus providing symmetrical bandwidth for upstream and downstream communication across~~ of a communication medium~~.~~ for the upstream and downstream communication channels. ~~The apparatus may be used for dual channel or multi-channel communications. The method may be implemented on a physical modem or a logical modem with the logical modem including a digital signal processor (DSP) coupled to an analog front end (AFE). The communication medium may include: wired, wireless and~~

~~optical. Orthogonality in either the time or frequency domains is injected into the individual symbols associated with each DMT tone set or between successive tone sets using a unique code, e.g. Walsh code, assigned to each transmitted channel. The mutual orthogonality of these codes allows two or more channels to be supported in either an upstream or downstream direction using a DMT line code, in connection with any of the various X-DSL protocols including: G.Lite, ADSL, VDSL, SDSL, MDSL, RADSL, HDSL, etc. The present invention provides a signal processing architecture that supports scalability of CO/DLC/ONU resources, and allows a significantly more flexible hardware response to the evolving X-DSL standards without over committing of hardware resources. As standards evolve hardware may be reconfigured to support the new standards.~~